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Training for Effective Human Supervisory Control of Air and Missile Defense Systems

by John K. Hawley, Anna L. Mares, and Cheryl A. Giammanco

ARL-TR-3765 **March 2006**

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14. ABSTRACT
One of the defining properties of the next generation of air and missile defense (AMD) command and control (C2) systems is an increasing reliance on automation. This report is the third in a series of three dealing with human performance and training issues in the development and effective use of automated AMD C2 systems. The first report (Hawley, Mares, & Giammanco, 2005) discusses the impact of automation on air defense operators and the consequences of their role change from traditional operators to supervisory controllers. The second report (Hawley & Mares, 2006) expands upon that background material and addresses the issue of developing effective human supervisory control (HSC) in AMD C2 systems. The focus of this report is training for AMD operators and the battle staff. In the words of the Army Board of Inquiry (BOI) investigating the Patriot fratricides that occurred during Operation Iraqi Freedom, it is necessary to re-look the level of expertise required to operate such lethal systems on the modern battlefield. Together, these reports are intended as a primer on automation, supervisory control, and effective human performance for commanders, concept developers, system designers, trainers, and other personnel involved with decision-making and operations for the next generation of AMD C2 systems.

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Executive Summary

One of the defining properties of current and future air and missile defense (AMD) command and control (C2) systems is an increasing reliance on automation. Technological opportunities and an increasingly complex operating environment have created a situation where AMD operators must be provided with automated decision support to meet mission objectives. There is a tendency among system developers with little background in human performance issues to assume that automation is innately beneficial. Research in a number of areas suggests, however, that such is not always the case. To begin, automation elevates operators into system monitors rather than active controllers. Operators are thus removed from moment-to-moment, active control and become monitors and managers of subordinate automated processes. It is a well-established fact that humans make very poor system monitors. Beyond classical vigilance, research and operational experience indicate that automation does not replace human operator tasks. Rather, it changes the nature of the work that operators do, and it does this in ways that are often unanticipated by system developers and users. Moreover, the preponderance of theory and empirical evidence suggests that the job of supervisory controller is quite different from that of a traditional operator. In a similar vein, it has been shown that automation does not reduce training requirements; it changes training requirements and often makes job preparation more demanding.

Other human performance problems associated with automation generally fall into one of two categories: (1) loss of situational awareness (SA) and (2) skill impairment. SA is important because it has been shown to be a key determinant of decision quality in battle command. Automation in and of itself does not prevent operators from establishing or maintaining SA or contribute to skill impairment. However, improper implementation coupled with inadequate or inappropriate training can make it more difficult for operators to establish and maintain SA and contribute to skill development and retention problems.

Much of contemporary automation applied to real-time C2 brings into play what has been called the Catch-22 of human supervisory control: Automation has been introduced because it is thought to be able to do the job better than human controllers, but humans have been left in the control loop to “monitor” that the automated system is performing correctly and to override the automation when it is “wrong.” The unstated assumption is that human operators can properly decide when the automation’s decisions should be overridden. Humans are expected to compensate for machine unreliability, but they suffer from a variety of cognitive limitations and vulnerabilities that make it nearly impossible to meet this expectation. A number of automation researchers have thus concluded that while the risks associated with automation unreliability can never be eliminated entirely, they can be managed more effectively through a number of positive actions directed at supporting and enhancing effective human supervisory control (HSC). These

actions generally fall into one of two categories: (1) design to support effective HSC, and (2) training to support effective HSC. This report addresses training to support effective HSC.

Section 1 begins with a brief review of results from the Patriot Vigilance project. This effort was concerned with the human performance contributors to fratricides involving the Patriot air defense missile system during Operation Iraqi Freedom. Recommendations from the Patriot Vigilance project indicated that the AMD community must address two primary problems associated with automation as applied in current Patriot operations: (1) developing effective HSC, and (2) the level of operator expertise required to employ a highly automated system such as Patriot on the modern battlefield. These issues are also relevant to AMD systems under development and to other Army systems being fielded to support network-centric warfare concepts.

Section 2 opens with a review of basic steps in the development of a good instructional program. In present context, a good instructional program is one that supports relevant practice with feedback leading to desired warfighting competencies. This section also includes discussion of relevant background research on the development of human expertise. The section concludes with a discussion of Training Demons, the enemies of good training. Training Demons are training outcomes and practices that occur when the rules of proper instructional design are not followed. These enemies of good training include: (1) inadequate job and task analysis, (2) misplaced training planning emphases, (3) lock-step versus criterion-referenced instruction, (4) content-based versus skill- and job-oriented training, (5) a misplaced emphasis on free-play versus deliberate practice, (6) inadequate or poorly-defined performance standards, (7) lack of emphasis on performance feedback, and (8) various forms of training folk wisdom that negatively impact training delivery.

Section 3 addresses six training dilemmas or issues that remain unresolved and stand in the way of moving AMD training away from its current focus on crew-drills in the direction of regarding operators as managers of lethal and complex systems. These issues include: (1) initial skill development, (2) time to train and job progression patterns, (3) training for unreliable automation, (4) team training, (5) training for adaptive expertise, and (6) mindfulness—developing crews and C2 teams that are capable of sustained high reliability in a complex and uncertain operational setting.

Finally, section 4 outlines a path forward for AMD. This section is developed in two parts: (1) training for routine expertise and (2) training for adaptive expertise—coping with automation unreliability and the inevitable fog of war. The subsection on training for routine expertise addresses six focus areas for improvement in AMD training for routine operations—when things work as they should. These focus areas are: (1) job and task analysis, (2) scenario content and training delivery, (3) performance standards, (4) time to reach desired competency levels, (5) qualified instructors, and (6) performance feedback—the after action review (AAR) process.

Training for adaptive expertise is intended to foster the ability to think “outside the box” defined by routine crew drills. Adaptive expertise is built on a solid foundation of the basics of AMD operations—training for routine expertise. Section 4 addresses the basic requirements for the development of adaptive individuals, crews, and teams. The discussion ends negatively by noting that three major roadblocks stand in the way of developing adaptive expertise: (1) training time and job progression practices, (2) training quality (aspects of the AMD branch’s traditional training practices), and (3) trainee motivation to develop as AMD professionals. Unless these roadblocks are confronted and remedied, adaptive crews and C2 teams are likely to be the exception rather than the rule. As the Defense Science Board has cautioned, the risk in leaving things mostly as they are is that training failures can negate promising technology and hardware.

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1. Background

1.1 Overview

One of the defining properties of the next generation of air and missile defense (AMD) command and control (C2) systems is an increasing reliance on automation. This report is the third in a series of three dealing with human performance and training issues in the development and effective use of automated AMD C2 systems. The first report (Hawley, Mares, & Giammanco, 2005) discusses the impact of automation on air defense operators and the consequences of their role change from traditional operators to supervisory controllers. The second report (Hawley & Mares, 2006) expands upon that background material and addresses the issue of developing effective human supervisory control (HSC) in AMD C2 systems. The focus of this report is training for AMD operators and the battle staff. In the words of the Army Board of Inquiry (BOI) investigating the Patriot fratricides that occurred during Operation Iraqi Freedom (OIF), it is necessary to re-look the level of expertise required to operate such lethal systems on the modern battlefield. Together, these reports are intended as a primer on automation, supervisory control, and effective human performance for commanders, concept developers, system designers, trainers, and other personnel involved with decision-making and operations for the next generation of AMD C2 systems.

1.2 Concepts and Terms

Prior to introducing the major topics in the report, it is necessary to define and clarify several terms that are used in the text. These definitions and clarifications are given in the paragraphs to follow.

Sheridan (1992, p. 3) defines automation as "the automatically controlled operation of an apparatus, a process, or a system, by mechanical or electrical devices that take the place of human organs of observation, decision, or effort." In contemporary AMD C2, the combination of operational complexity and technical advances have led to a situation in which functions—perception, decision-making, response selection and implementation—assigned to the human subsystem in previous generations of AMD systems are now assigned to the machine subsystem.

Supervisory control is defined as a situation in which "one or more operators are continually programming and receiving information from a computer that interconnects through artificial effectors and sensors to the controlled process or task environment" (Sheridan, 2002, p. 115). Under a supervisory control regimen, operators do not interact with the controlled process directly, as they previously did in manual or less automated systems. Rather, the operators receive information from and provide input to a computer, which, in turn, directs the controlled process. The operator's role is thus changed from direct, on-line process control to supervisor of a mostly computer-directed process. Their job is to supervise the computer controller. The

consequences of this role transformation—though often subtle—must be reflected in system design, performance support feature (i.e., job aiding), and operator-controller[1] training and professional development.

Effective HSC means that AMD operator-controllers are able to carry out their explicit role, which is to supervise or direct subordinate automated control systems. Effective HSC implies *meaningful human oversight*, where meaningful human oversight means that operator-controller supervision of subordinate automated control systems is actual and not theoretical or abstract. A third related term, *positive human control*, is a specific aspect of effective HSC and meaningful human oversight. Positive human control means that firing decisions—to shoot or not to shoot—are based on conscious problem solving and discernment and not merely the result of automation bias, or uncritical acquiescence following the system's recommendation.

Knowledge refers to background information required in the performance of a job or task. Knowledge is sometimes described as "knowing about." *Skill* refers to a task or group of tasks performed to a specific level of proficiency, which often use motor functions and typically require the manipulation of instruments or equipment. Some skills are knowledge- and attitude-based and do not require equipment manipulation. Skills are sometimes characterized as "knowing how to do." A *competency* is a set of skills performed to a specific standard under specific conditions. Competencies are sometimes characterized in terms of the *level* of knowing how to do. Competencies differ from task standards in that they are whole-job-referenced rather than individual task referenced.

1.3 The Patriot Vigilance Project

Personnel from the Army Research Laboratory's Human Research and Engineering Directorate (HRED) began looking into Patriot and AMD performance and training issues at the invitation of the then Ft. Bliss Commander, MG Michael A. Vane. MG Vane was interested in operator vigilance and situational awareness (SA) as they relate to the performance of automated AMD battle command systems. The generally accepted definition of SA is from Endsley (1996) who defines it as the *perception* of elements in the environment, the *comprehension* of their meaning, and the *projection* of their status in the near future. MG Vane was particularly concerned by what he termed a "lack of vigilance" on the part of Patriot operators along with an apparent "lack of cognizance" of what was being presented to them on situation displays with an ensuing "absolute trust in automation." His request for human engineering support was prompted by an unacceptable number of fratricide incidents by Patriot units during OIF.

[1]To differentiate traditional manual operators from operators performing in a HSC setting, these latter personnel are referred to as "operator-controllers."

The project staff spent most of the summer and fall of 2004 performing a root cause analysis of the OIF fratricide incidents—reading documents, interviewing knowledgeable personnel in the Ft. Bliss area, and observing Patriot training and operations. An initial report was delivered to MG Vane in October 2004. A discussion of the results of what was termed the Patriot Vigilance project is presented in Hawley and Mares (2006) and is not repeated here, other than in a summary manner. HRED's report to MG Vane in October 2004 recommended two primary actionable items to redress the performance problems identified during the Patriot Vigilance effort:

1. Re-define the operators' roles to provide meaningful human oversight of system operations, and
2. Develop more effective Engagement Operations (EO) personnel, particularly the air battle operations (ABO) slice of EO—re-look the level of expertise required to operate such a lethal system on the modern battlefield.

The Defense Science Board (DSB) (DSB, 2004) reinforced HRED's recommendations with the following comments. Although the full DSB report on Patriot system performance is classified, these extracts are not.

> The Patriot system should migrate to more of a "man-in-the-loop" philosophy versus a fully automated philosophy—providing operator awareness and control of engagement processes.

and

> Patriot training and simulations should be upgraded to support this man-in-the-loop protocol including the ability to train on confusing and complex scenarios that contain unbriefed surprises.

The key notion in the first DSB recommendation is captured in the phrase, "providing operator awareness and control of engagement processes." Simply put, Soldiers and not the automated system must be the ultimate decision makers in AMD engagements. Decisions to shoot or not to shoot must be made by crews having adequate SA and the expertise to understand the significance of the information available to them. The DSB's first recommendation is synonymous with HRED's first actionable item concerning establishing meaningful human oversight of Patriot and other AMD systems.

The second DSB recommendation having major significance for human performance in contemporary AMD operations concerns operator-controller training and professional development. Here, the DSB supported HRED's conclusion that it is necessary to re-look the level of expertise necessary to operate such a lethal system on the modern battlefield. To highlight the importance of the training issue, the fratricide BOI stated bluntly "The system [Patriot] is too lethal to be placed in the hands of crews trained to such a limited standard."

The BOI examining the OIF fratricides specifically criticized Patriot training for emphasizing "rote drills" versus the "exercise of high-level judgment." The essence of this criticism is that the user community approaches training for a complex, knowledge-based function like ABO in much the same manner as linear, skill- and rule-based actions like March Order and Emplacement or System Set-up. The emphasis is on mastering routines rather than adaptive problem solving. However, the range of actions required in routine drills is narrower and more predictable than those encountered in combat operations.

The U.S. Navy faced a similar reconsideration of training practices in the aftermath of the shoot-down of the Iranian airbus by the USS Vincennes in 1988. After more than 10 years of research, the Navy reached several conclusions that are also relevant to the contemporary AMD setting. First, the Navy's research concluded that Aegis operator-controller training must emphasize the development of adaptive decision-making skills. Adaptive decision-making skills, or the ability to think outside the box defined by routine crew drills, are a key aspect of effective operator-controller performance in ambiguous situations. The second major conclusion was that shipboard (i.e., unit) training must address team in addition to individual performance. Competent crews are the basis of effective unit performance, and crews are more than the sum of their individual members. Both of these issues are addressed explicitly in the sections to follow.

The DSB's recommendation to include unbriefed surprises in training does not mean that it is sufficient merely to insert anomalous events like those encountered in OIF into training scenarios. In advanced AMD training, the scenario is the curriculum. To properly prepare operator-controllers for combat, scenario designers must bear in mind that the surprises of OIF are representative of a class of potential anomalies. Selected anomalies occurred then; others—some similar, some different—will occur on future battlefields. It is thus necessary that operator-controllers be imbued with a sense of mindfulness that automated battle command systems are fallible. The system's recommendations will be correct most but not all of the time. Training must foster the development of the expertise essential to recognize potential anomalies and the skills necessary to determine an appropriate course of action. Operator-controllers must walk a fine line between blind faith and wholesale mistrust. AMD decision makers must not underestimate the difficulties associated with adequately meeting this training challenge.

1.4 The Rest of the Report

The idea for this report grew out of a conversation with the Army Training and Doctrine Command (TRADOC) System Manager-Lower Tier (TSM-LT), during which he suggested follow-on reports addressing two topics beyond those addressed initially in Hawley, Mares, and Giammanco (2005):

- Design for effective HSC of AMD systems
- Training for effective HSC in AMD operations

The present report addresses the second follow-on topic: Training for effective HSC. In the next section, we begin this treatment with a discussion of core training issues in AMD. A section addressing various unresolved training issues for research and experimentation follows this opening discussion. Finally, we discuss a path forward for AMD. The path forward addresses elements of training to develop both routine (that required for normal operations) and adaptive expertise (that required for situations that are not typically encountered during routine operations). In keeping with the focus on effective HSC, the discussion to follow emphasizes training for AMD ABO—activities performed by Patriot crewmembers in the battery-level Engagement Control Station (ECS) and at the battalion-level Information and Coordination Central (ICC).

2. Core Training Issues: Revisiting the Basics

2.1 Training Preliminaries

Training is a *process* by which job-relevant knowledge, skills, and competencies are acquired by individuals, crews, and multi-echelon units. In a military setting, its purpose is to deliver warfare *competence* where and when it is needed (DSB, 2003). The DSB report further notes that training consists of *relevant practice* with *feedback*. In essence, therefore, training is a process by which *learning* at various levels (individual, crew, or unit) is facilitated.

Training is not simulations, networks, virtual environments, or games even if they are labeled as training devices. All of these mechanisms can be used to craft an environment in which learning *might* take place, but they are not training *per se*. This is an important distinction: Various methods and technologies such as those mentioned above can be used to support training if they provide an environment in which job-relevant practice with appropriate feedback can occur. Training developers must, however, first know what must be practiced and the appropriate form of essential feedback.

A good instructional program is defined as one that supports relevant practice with appropriate feedback leading to desired warfare competencies. Developing a good instructional program is a relatively simple process. However, the devil can be in the details of how the various steps in the process are carried out. The steps in proper instructional design are listed as follows (Whitmore, 2002):

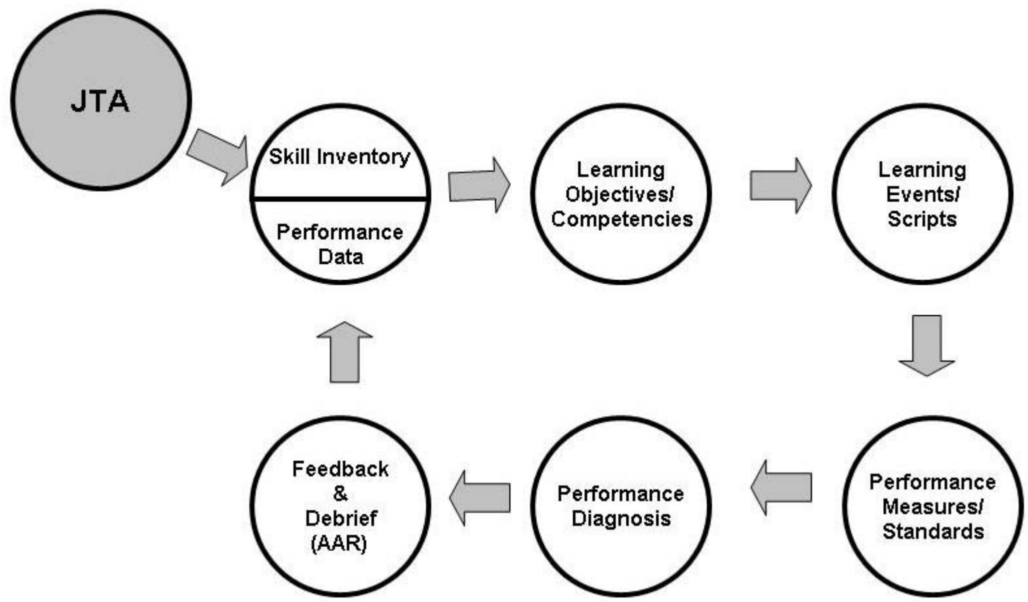
1. Specify the job performances we want trainees to learn to do.
2. Break those job performances down successively into their component activities (including mental activities) until we reach the level of skill already possessed by the trainees.

3. Develop situations that lead trainees through those things we want them to learn to do.
4. Lead trainees through practicing the new activities, beginning with the lowest level and successively assembling higher-level activities from lower-level components.
5. Provide trainees with sufficient practice—with feedback—at each level to reach desired competency levels.

Steps 1 and 2 comprise what is often called a Job and Task Analysis (JTA), or Front-End Analysis (FEA). Step 3 is an aspect of course design, specifically scenario design. Steps 4 and 5 describe proper instructional delivery. Taken together and without all of the detail, this process is conceptually similar to what is called for in the Instructional Systems Development (ISD) process or its Army variant, the Systems Approach to Training (SAT).

Before leaving the present topic, we want to comment on the importance of the JTA. The information obtained from a JTA must be based on a system's contemporary operating environment and not simply reflect a subjective update of job and task analysis material from a previous era. Training developers are often tempted to pursue this latter course of action because comprehensive job and task analysis can be an expensive and time-consuming undertaking. A thorough job and task analysis must be a high priority for current systems being used in mission settings different from that originally intended (e.g., Patriot against a tactical ballistic missile [TBM] threat) and for all follow-on systems. Competent JTA involves much more than simply updating an existing task list along with supporting documentation. In their 2003 report, the DSB remarked that a recurring problem with Army training is that a JTA is rarely performed properly, and this "original sin" returns to haunt Army training over the life cycle of most systems.

It has been noted that for a dynamic, performance-based setting like AMD ABO, the scenario is the curriculum (Cannon-Bowers, Burns, Salas, & Pruitt, 1998). The relevant practice and feedback essential to developing warfare competence takes place within a simulation-based learning environment. In this setting, training scenarios provide the structure within which the stimulus and response aspects of learning are presented and evaluated. The process by which effective scenario-based training is developed and implemented is depicted in figure 1.



Source: Adapted from Cannon-Bowers, Burns, Salas, & Pruitt (1998)

Figure 1. Scenario-based training cycle.

From figure 1, results from the JTA are used to prepare a skill inventory, or list of job skills to be trained. These job-relevant skills are used to develop a list of learning objectives and associated competencies. Learning objectives drive the development of scenario events, or scripts. If you want a trainee to learn how to do something, then the training scenario must provide the stimuli necessary to elicit that behavior. Next, the training developer must define performance measures and standards. A performance measure is a behavioral description that permits an evaluator to unambiguously decide whether a performance took place. The performance standard provides a way of judging whether that performance was acceptable.

In performance-oriented training, feedback is just as important as performance evaluation. For learning to occur, trainees must be provided with feedback regarding their performance along with corrective guidance. Accordingly, the next step in the Scenario-Based Training Cycle is performance diagnosis: If the performance was not acceptable, why not? Performance diagnostic information provides the basis for the feedback and debrief stage, or After Action Review (AAR). Performance diagnosis must be objective and specific to the performances involved. Moreover, for best effect, feedback should be immediate with an opportunity to practice less-than-successful performance elements.

2.2 The Development of Expertise

Throughout this series of reports we have referred repeatedly to operator-controller expertise. In present usage, the term expertise refers to a capability for consistently superior performance on a specified set of representative tasks for a domain (Ericsson & Lehmann, 1996). Expertise in

AMD ABO is derived from all aspects of operator-controller job preparation: (1) traditional training (institutional and unit), (2) professional development (self-directed study and professional military education), and (3) relevant on-the-job experience.

We have also argued that SA is the key factor determining decision quality in battle command (Hawley, Mares, & Giammanco, 2005). SA is built upon in-depth technical and tactical expertise. The primary implication of this conclusion is that marginally-skilled or apprentice operator-controllers cannot develop the SA necessary for effective supervisory control, regardless of the sophistication of the battle command hardware suite provided to them. Technology can support and amplify human expertise, but cannot substitute for it.

Given the centrality of operator-controller expertise to effective AMD C2, an obvious follow-on question is, “How is such expertise developed?” Norman (1993) notes that there are at least three phases of learning leading to expertise as defined above. These are (1) accretion, (2) tuning, and (3) restructuring. Accretion is the accumulation of facts (knowledge in our terminology). When the learner has a proper conceptual framework or mental model, accretion is easy, painless, and efficient. Without a good conceptual framework, accretion is slow, tedious, and error-prone.

Tuning refers to the process of translating knowledge into skill. This requires a hands-on learning environment and hours and hours of practice under the supervision of a coach or mentor. How many hours are necessary? Norman (1993) asserts that for any complex activity, a minimum of 5,000 hours of practice (two years of full-time effort) are required to turn a novice into an entry-level expert. Other researchers such as Ericsson and Charness (1994) put the time estimate for transitioning from novice to expert at 10,000 hours of practice. It all depends on one’s definition of an expert.

The final stage of learning is restructuring, or forming and reforming the proper conceptual structure for performing as an expert. Norman (1993) remarks that accretion and tuning are primarily experiential—they take place actively in an experience-based learning environment. Restructuring is reflective. It involves exploring the domain in depth, forming comparisons, and integrating across related domains. Accretion and tuning can be done within a traditional training setting. Restructuring is a professional development activity; it is best done as self-directed study or as part of formal professional military education.

Norman also comments that one of the problems associated with the development of expertise is making trainees want to do the hard work necessary for restructuring. Ericsson and Charness (1994) support Norman’s view and assert that a trainee’s motivation to attend to the task and exert effort to improve his or her performance is critical to development as an expert performer. Training managers delude themselves if they believe that skilled performance is easy and can come about without extended effort on the part of trainees.

The bottom line for the previous discussion is clear: Practice is the major independent variable in skill acquisition and the development of expertise—but not just any kind of practice. Ericsson and Charness (1994) assert that skilled performance is not an automatic consequence of simply having more experience with an activity. Skilled performance is developed through what is referred to as “deliberate practice.” Deliberate practice is a long period of active learning during which job performers refine and improve their skills under the supervision of an instructor or coach. It requires a commitment to hours and hours of relevant practice with expert feedback.

Several times throughout the previous discussion, we have alluded to the importance of a proper conceptual framework or mental model in learning and job performance. A mental model is a job performer’s internal understanding of how a performance situation works or fits together. It permits job performers to make sense of a performance situation and his or her role in successful performance. Norman (2002) remarks that a good mental model permits equipment users to predict the effects of their actions. Without a good model, users perform as they are told without really knowing why. As long as things work, they can manage. However, when things go wrong or when the unexpected happens, users frequently are at a loss as to how to proceed.

Mental models also can be an aid to effective instruction. We noted above that a proper mental model facilitates accretion. Without one, trainees are forced to engage in a rote memorization drill that is tedious and error-prone. Also, material learned in this manner is not easily retained or generalized. Further, in the tuning phase of learning, mental models serve a similar purpose. They help trainees make sense of what they are being asked to do. It is easier to learn and retain something that makes sense as opposed to something that does not. A word of caution is in order here: Trainees will develop mental models on their own if not provided with them as part of the instruction—and these may not be accurate or entirely appropriate. Inappropriate mental models can work against the objectives of the training program.

2.3 Training Demons: The Enemies of Good Training

To close the present section, we provide a list of Training Demons, or enemies of good training. These are things that we have observed routinely in AMD and Army training. They illustrate what can happen when training development and delivery are conducted without regard for the basics as described in the previous subsections.

1. Inadequate job and task analysis: Not understanding what to train. A competent JTA is the primary input to the instructional development process. Training is only as good as its analytical basis. To the extent this analysis is incomplete or inadequate, trainers run the risks associated with the GIGO phenomenon: Garbage In-Garbage Out.

2. Misplaced training planning emphases: Media dreams, training fads, and silver bullets. We remarked earlier that exotic media, games, simulations and other “enhanced” training environments are not training *per se*. They can be used to support learning, but their effective use is predicated on a comprehensive understanding of (1) what must be trained,

(2) a proper performance setting for relevant practice, and (3) feedback requirements. In training, there are no silver bullets.

3. Lock-step, time-based versus criterion-referenced instruction. Much of AMD and Army training is lock-step (everyone moves through the curriculum at the same pace and finishes at the same time) and time-based (shoe-horned into a fixed allotment of time). Training-to-standard, or criterion-referenced instruction, does not fit well into such a straight jacket. People do not learn at the same pace. Course lengths must be based on a consideration of what must be trained, competency requirements, and how long that learning process is expected to take. Arbitrarily fixing course lengths simply means that some knowledge and skills will not be learned to standard, and this will likely be reflected down-stream in inadequate on-the-job performance. Exit criteria from training must be some level of proficiency, not a fixed number of hours of class time.

4. Content-based training. Content-based training is most often encountered in academic instruction. Its purpose is to teach students about something, not to teach them how to do something. Classroom training is not an adequate approach to training skills—how to do something. People learn to do by doing. Content-based training is often a workaround for an inadequate JTA. We do not know in detail what the job requirements will be, so we teach about the job rather than how to do it.

5. Not understanding that free-play is not deliberate practice. As noted earlier, deliberate practice is essential to the development of job competence. This is training conducted under the close supervision of a master performer with frequent constructive feedback. From our observation, much unit-based training in AMD is more like free play. Trainees perform within the context of a scenario without close supervision and the relevant feedback that goes with it. Based on the JTA, scenarios must be written to provide the kind of structured training and practice required for skill development. Further, there must be multiple scenarios for the practice of any particular skill. Hence, scenario construction, based on the JTA, is a high priority for effective training. Free play affords few opportunities for effective learning and skill development.

6. Inadequate or poorly-defined standards. A review of AMD and Army training publications reveals page after page of tasks, conditions, and standards, sometimes very detailed. The task-standard approach to assessing training success might be appropriate for a linear function like March Order and Emplacement or System Set-Up. But, for a complex, knowledge-based job like AMD ABO, individual task performance standards are not enough. The ABO job is not performed as a series of individual, sequential tasks. It is entirely possible that a trainee could successfully meet each task performance standard in sequence, yet be "clueless" about overall job requirements—fighting the air battle. The OIF BOI alluded to this possibility with its remark that "The system [Patriot] is too lethal to be placed in the hands of crews trained to such a limited standard." In a knowledge-

based setting like ABO, standards must address performance requirements for the whole job or for meaningful job segments as opposed to individual tasks. Individual task standards might be useful during early phases of ABO training, but they are not suitable for later tactical training. The ABO job is more than the sum of its individual task parts.

7. Lack of emphasis on the AAR process. Proper feedback or knowledge of results is essential to learning. With respect to AMD ABO, research indicates that proper feedback is a critical factor in improving decision accuracy (Kozlowski, 1998). In a discussion of air-defense-specific results, Bisantz, Kirlik, Gay, Phipps, Walker, and Fisk (1997) assert that knowledge-oriented training for complex judgment tasks must address the skills required to consistently execute judgments based on that knowledge. Trainees must be taught why their decisions were good or bad. This requires close and continuous contact with a master performer acting as coach.

8. Training folk wisdom. Folk wisdom refers to beliefs about a subject area that are based on personal experience uninformed by theory or broader empirical results. In the training domain, folk wisdom is exhibited in statements like “Everybody’s a trainer” or “This is the way we’ve always done it. It worked for me, and it’ll work for them.” Roth (1998) remarks emphatically that job performance and unit experience do not imply instructional competence. Training and learning are serious, technical activities. Not to regard them as such invites many of the problems alluded to in the first seven of these Training Demons.

3. AMD Training Dilemmas: Issues for Research and Experimentation

3.1 Overview

If the AMD ABO job setting were like most others in the Army or like those that dominated in the past, it would be possible to stop our training discussion here. The basics described in the previous section, if properly applied, would be sufficient to provide competent job performers. However, that is not the case. Compared with routine Army jobs, the AMD ABO job setting has more of the following characteristics:

1. Complex
2. Ambiguous and uncertain
3. Non-linear
4. Knowledge-intensive

Earlier, we commented on the importance of a comprehensive and up-to-date JTA in developing good training for a job like AMD ABO. Two of the characteristics listed above make conducting a JTA for such jobs more complex than with routine jobs. First, in most Army jobs (including many AMD jobs) task sequences are linear. This means that tasks are executed in a designated sequence: A to B to C to D, and so on. Branches in the task sequence are governed by relatively well-defined rules: If (Situation), Then (Task E), Else (Task F). Conventional time and error metrics can be used as the basis for performance standards.

In a non-linear job, the task sequence is not so well defined. Instead of linear task *sequences*, there are non-linear task *networks*. Moreover, for knowledge-intensive jobs, conscious problem solving and decision-making—based on cues from the operating environment—dictate which actions are performed and in what order. Non-linear, knowledge-based performances also introduce varying degrees of equifinality into the task network. Equifinality means that there is more than one path through the task network that leads, essentially, to the same outcome. These aspects of the AMD ABO job do not fit conveniently into traditional JTA concepts. Moreover, traditional task time and error metrics can be problematic in the presence of equifinality.

The job characteristics listed above also require that training for the ABO job be approached differently than more routine activities. A failure to do so on the part of the AMD training community was the principal reason for the OIF BOI criticism that Patriot training emphasized rote drills rather than flexible problem solving. Jobs characterized by the features listed above cannot be adequately trained outside of a problem-solving context. Such jobs also place a premium on jobholder expertise. Preparation for them will require an expansion of the Branch's views regarding training in the direction of what has been more typically regarded as education. Traditionally, training has been viewed as preparation for a job that can be fully characterized by the results of a conventional JTA. Education, on the other hand, has been viewed as appropriate for jobs that cannot be so neatly circumscribed. Under a supervisory control regimen, operator-controller jobs have evolved away from traditional operator in the direction of system manager. What the Army has traditionally called training also must evolve to reflect this change in job orientation.

Within the AMD ABO performance domain, we have identified six training-related dilemmas or issues for follow-on research and experimentation. These are issues that remain unresolved and thus stand in the way of moving ABO training away from its current crew drill orientation in the direction of regarding operator-controllers as managers of lethal and complex systems. These dilemmas are:

1. Initial skill development
2. Time to train and job progression
3. Training for unreliable automation
4. Team training

5. Adaptability
6. Mindfulness

Each of these issues is addressed separately in the subsections to follow.

3.2 Initial Skill Development

It is a fact of life that future AMD C2 systems will involve considerable automation and accompanying HSC. More than two decades ago, Bainbridge (1983) first commented on one of the apparent ironies of automation: An automated performance environment often does not provide a good training setting. From a skill development perspective, automation introduces a special problem not encountered in less complex systems. In manual systems, operators can develop their skills progressively as they move from simple operating situations to more complex tasks. Automated systems, on the other hand, often represent an all-or-nothing situation. They do not require—and sometimes prevent—direct operator participation in the control process. Therefore, an automated performance environment might not support progressive skill development. This also means it might not be suitable to use actual equipment with embedded training for all phases of operator training.

Klein (2003) discusses a second skill development problem associated with automated systems. He remarks that "smart" technology (like that associated with automation) can make operator-controllers "stupid" (ineffective as decision makers) in three ways:

1. By disabling the expertise of controllers who are already skilled.
2. By slowing the rate of learning so users do not develop appropriate levels of expertise.
3. By reinforcing dysfunctional skills that will interfere with users' ability to achieve expertise in the future.

In the first case, Klein notes that the information screening and filtering often associated with automation prevent operator-controllers from finding the information they need to make decisions. Operator-controllers thus are denied access to some or all of the decision-cueing information essential to effective decision making. One might say that operator-controller decision making can be inadvertently short-circuited through data display and access decisions made by system developers, who often are not familiar with tactical performance requirements.

Second, the same information screening and filtering alluded to in the previous paragraph can deny novice or journeyman controllers access to the data necessary to form the associations between cue sets and environmental patterns that are essential to effective decision making. In the first case, information filtering prevents current experts from performing as experts. That same filtering can prevent new operator-controllers from ever developing into experts.

Klein's third aspect of decision-making impairment involves reinforcing dysfunctional coping practices within the automated environment. Here, operator-controllers become passive

recipients of information from the machine. Klein notes that this passivity tends to make new users reluctant to work around problems or strike out on their own to become true experts. They lack the background to do so. He further remarks that new users lose or never develop their ability to look and search critically within the tactical environment. Smart technology has made them passive and ineffective as problem solvers.

Rasmussen (1986) remarks that in an automated setting the skills required for successful performance during extreme situations are not always developed or maintained during normal training or operations. He cites three reasons for this potential problem:

1. Unknown but latent system faults cannot be simulated.
2. System behavior may not be known for faults that can be predicted but have not been experienced.
3. What was abnormal becomes routine.

The first two bullets above are self-explanatory: Things will happen that have not been anticipated or experienced and thus cannot be explicitly trained. In the third situation, what was once considered abnormal enters the training program and becomes routinized over time and repetition. The tendency here is not to regard the abnormal situation as representative of a potential class of abnormal situations that might occur, but just another isolated fault that has been identified and corrected. This illustrates the danger of simply incorporating unbriefed surprises in training scenarios without emphasizing these anomalies within a context of adaptability and mindfulness.

With respect to initial skill development, the issue to be resolved going forward is simply stated as follows: Is it necessary to learn first in a less automated performance setting? Can jobholders adequately master their ABO role if training is conducted solely in an automated practice environment? The research results in this area suggest that automation itself might be an impediment to the development of the level of expertise required for effective ABO performance.

3.3 Time to Train and Job Progression

Traditionally, one of the primary articles of faith in Army training is that personnel must be trained effectively. Trainees must acquire all of the skills needed to perform all of the tasks needed to meet the missions or goals and objectives of the system. Not to do so is to open the door to poor on-the-job performance and possibly to court military disaster. In section 2, we noted that deliberate practice is the major independent variable in skill acquisition. Moreover, the amount of time devoted to training must be based on a consideration of what must be trained and standards for acceptable on-the-job performance. Arbitrarily fixing school course lengths or the duration of on-the-job training (OJT) means that some knowledge and skills will not be

learned adequately, and this deficiency will be reflected downstream in inadequate on-the-job performance.

Section 2 also raises another controversial topic: The amount of time in deliberate practice required to progress from novice to introductory master performer. A figure of 5,000 hours, or two years of full-time instruction, was cited as the minimum amount of time required to quality as an entry-level expert. Those figures being on the table, let us consider how much training time is currently allocated for U.S. Army Patriot personnel to progress from novice status (no Patriot-specific training) to qualification as a Tactical Control Officer (TCO) or Tactical Control Assistant (TCA). Estimates vary, but following conversations with subject matter experts (SMEs), we arrived at the following times. For officers, the estimate is about eight months. This includes approximately four months of Patriot Weapons Track Training as part of the Officers' Basic Course followed by as little as four months of OJT. For enlisted personnel (MOS 14E), the Patriot Fire Control Enhanced Operator-Maintainer course during Advanced Individual Training (AIT) lasts 19 weeks. However, more than half of 14E AIT is taken up with maintenance topics. The other portion is taken up with ABO training. Following the nearly five months of AIT, a new 14E could qualify as a TCA with as little as four months of OJT at his or her assigned unit—nine months total. These estimates are clearly short of the two years cited in the literature for developing in-depth job expertise.

As part of our exploration of the time-in-job-preparation issue, we also examined training patterns for two benchmark cases:

1. Israeli Patriot
2. FAA en route air traffic controllers (ATCs)

Israeli Patriot operators first undergo four months of initial training, which qualifies them as a low-level TCA. As a low-level TCA, trainees are allowed to observe in the ECS under supervision and perform other battery duties. Trainees remain low-level TCAs for four months to one year, depending on their performance-based skill progression. After completing their stint as a low-level TCA, trainees undergo an additional two months of high-level TCA training. Upon successful completion, they become high-level TCAs and perform as a squad leader.

The "best" sergeants to complete the high-level TCA course and other leadership courses are selected as officer candidates. Selection as an officer candidate is followed by a three-month officer's basic course and a four-month air defense (AD) officer's course (seven months total). Trainees then return to their unit to serve as a low-level TCO. As a low-level TCO, they are not assigned to an active crew that responds to real-world alerts.

After an additional year in the unit with extensive simulation-based training, trainees can qualify for promotion to first lieutenant (1LT). Promotion to 1LT is followed by two additional months of training in AD tactics. Successful completion of the tactics course qualifies the trainees as high-level TCOs. As a high-level TCO, the officer can serve during alerts as part of a three-

officer ECS crew consisting of 1LTs and captains. In total, a minimum of 31 months of training interspersed with unit experience is required for qualification as a TCO.

Additional relevant features of Israeli Patriot training include the following:

- All TCA and TCO training is strictly on ABO
- ICC Tactical Directors are selected from tactical ECS crews and undergo an additional six weeks of training
- OJT is simulation-based
- Periodic hands-on exams are required following certification
- Disqualification from alert status is automatic upon failure of an examination

The job of an FAA en route ATC is conceptually similar to a Patriot operator-controller, albeit with different ends in mind. To begin the process of becoming an en route controller, job candidates undergo a battery of pre-training selection instruments looking at both trainability and aptitude for the ATC job. Candidates who pass the pre-training screening phase move on to the FAA Academy in Oklahoma City, OK, for four months of intensive resident instruction on en route operations. Much of the Academy's training is simulation-based with a roughly 1:2 student-to-instructor ratio. One instructor serves as a real-time mentor, while the other performs discrete skill checks. Essentially, academy hands-on training is tutorial, with the tutors being retired ATCs.

Following successful completion of Academy training, controller candidates return to their assigned center for an additional two to three years of apprenticeship, depending on the complexity of the air sectors at that center. Certification—being able to sit at the scope and direct traffic alone and without supervision—is performance-based and also depends upon a mentor's assessment of readiness for full certification. Total time to full performance certification as an en route ATC is 28-40 months. Should a controller move from one center to another, the OJT process starts over. However, once qualified, an experienced controller may progress through the OJT sequence faster than a new trainee.

Job preparation times in each of these cases are considerably longer than the time allocated for training in U.S. Army Patriot. Both benchmark situations also are consistent with the literature in that more than two years of preparation precedes being declared qualified for an operational position. The benchmark situations also illustrate the time-honored preparation sequence for a high-skill job: trainee to apprentice to journeyman, with extensive job sample testing along the way. Both are also characterized by spending a considerable amount of time in the operational setting apart from formal training. The FAA has observed, for example, that spending time in the job setting prior to the onset of formal training has a positive impact on performance during training. Trainees who have spent time in the organization as an observer-apprentice appear to be better able to take advantage of formal training when it is offered. They progress through the

training sequence faster and academic attrition is lower. Spending time in the operational setting apart from formal training permits trainees to acquire what Sternberg et al. (2000) refer to as "tacit" knowledge. Tacit knowledge is job-relevant information that is personally important to the learner. It has been found to enhance "practical intelligence," or the ability to find the best fit between trainees and their work environment.

We are not saying that either the FAA or the Israelis have the "right" answer for how long training should take for a job like that of Patriot operator-controller. It is worth noting, however, that in both benchmark instances the organizations in question keep their job candidates in a preparatory status far longer than the U.S. Army—more than three times as long. Given the negative comments on Patriot training coming out of OIF, the issue of training time and preparation sequence for Patriot operator-controllers must be re-examined. Training time is clearly an issue for research and experimentation. It must not be dictated solely by bureaucratic constraints or administrative considerations.

3.4 Training for Unreliable Automation

One of the unmistakable conclusions from OIF combat operations is that the Patriot system's automation is not perfectly reliable (see Hawley & Mares, 2006). Reliability is defined as being dependable or capable of being relied upon. Extending this basic definition to real-time C2 as in AMD battle command, a reliable automated system is one in which the functions assigned to the machine are performed accurately and appropriately.

Research indicates that if operator-controllers have a choice, trust in automation determines usage. Simply put, operator-controllers will elect not to use a system they do not trust (Lee & Moray, 1992). This same body of research also suggests that trust in automation is affected by the same factors that influence trust between individuals: effectiveness and reliability (Muir, 1988). In the case of AMD C2, operator-controllers do not have a choice. They must use the system they are provided. So let us next consider the issue of training for situations in which the automation is not perfectly reliable.

Rovira, McGarry, and Parasuraman (2002) remark that one of the true "ironies" of automation is that the more reliable the automation, the greater its detrimental effects when it does fail. Repeated successful use lulls operator-controllers into a false sense of security or complacency regarding the automation's performance. These authors also report results indicating that operators become over-reliant on automation when it provides decision and action choices for them and do not check underlying information choices as carefully as when such choices are not provided explicitly. Near-perfect automation will lead to a situation in which operator-controller decision making is biased in favor of uncritically accepting the automation's recommendations.

Wickens, Dixon, and Ambinder (2005) present results indicating that imperfect automation is *manageable*, but users must be pre-warned of the nature and source of the automation's

imperfections. These authors also caution that reliabilities less than 75% are worse than no automation at all, and can provide users with what they term a "concrete life preserver."

Cohen, Parasuraman, and Freeman (1997) and Masalonis and Parasuraman (1999) argue that trust in automation should not be all-or-none, but graded and differentiated according to the operational context. These authors refer to this as *situation-specific* trust. The automation may work very reliably in certain contexts, in which the operator should use it and trust it. But in certain other cases, that the operator-controller has been trained to look for, the automation's recommendations may be suspect. Operators should be told to assess the situation and take the action that best suits the context, in their judgment. If operator-controllers can be trained to recognize the appropriate context, then they can know when to trust the automation and when its recommendations should be discounted.

In a similar vein, Lee and See (2004) assert that automation should be designed for *appropriate* as opposed to *greater* trust—based on the automation's expected reliability in handling various functions. These authors go on to state that in situations involving imperfect automation, operator-controller training must emphasize:

1. Expected system reliability
2. The mechanisms underlying potential reliability problems
3. How usage situations interact with the automation's technical characteristics to affect reliability

The implications of this brief discussion of automation reliability and its impact on training are clear: System developers and users must be brutally honest regarding automation reliability. Extensive tests must be performed to determine those situations in which the automation does not meet design criteria for reliability. Boundaries of successful system performance must be pushed. Moreover, the mechanisms underlying unreliable performance must also be explored. Commanders and operator-controllers must then be apprised of system unreliability patterns and trained in situations that will expose them to system imperfections. Meeting this challenge will be a tall order. It is not clear that even well prepared operator-controllers will be able to make the decisions necessary to realize situation-specific trust. Much research and experimentation on this issue is required. A good starting point for this work might be the Lens Model approach to assessing Dynamic Decision Making performance advocated by Bisantz and her colleagues (Bisantz, Kirlik, Gay, Phipps, Walker, & Fisk, 2000; Jha & Bisantz, 2001).

3.5 Team Training

It has been noted that units, not individuals are the basis of warfare competence (DSB, 2003). This is not to say that individual performance is not important. Individual performance is an important component of crew and unit performance. But for the most part, individuals do not perform missions. Crews and units do.

It is also an accepted fact that a crew is more than the sum of its individual parts, and melding the disparate parts into a functioning unit takes time working together. Proper performance at the crew level requires that individual crewmembers be aware of their interdependencies (Kozlowski, 1998). A variety of recent research and operational results suggests that managing crew interdependencies may require team process training similar to the Crew Resource Management (CRM) programs prevalent in the aviation community. Once almost exclusively an aviation program, CRM is now broadly viewed as the use of all available human, informational, and equipment resources toward effective and efficient operations in operational domains dependant on crew or team performance (Helmreich, Merritt, & Wilhelm, 1999). In the aviation world, CRM skills are viewed as a primary line of defense against human error and its consequences. The FAA also uses CRM principles to foster cooperation and coordination among the controllers in ATC centers.

Several additional points regarding the development of effective crews are listed as follows:

1. Effective team training is based on solid individual technical training
2. Time to train is a key neglected issue in developing effective crews
3. Leaders are central to the crew development process

In the first case, it goes without saying that a team is no more able than its least effective member. Hence, competent crews first require competent individuals. Second, as we noted at the outset, developing effective crew performance takes time working together. It is essential that training plans be based on an understanding of how organizations acquire competence. As shown in figure 2, competence is developed from the ground up: individuals, then crews, and finally multi-echelon units. Inadequate training at any point in the performance chain can short-circuit the process.

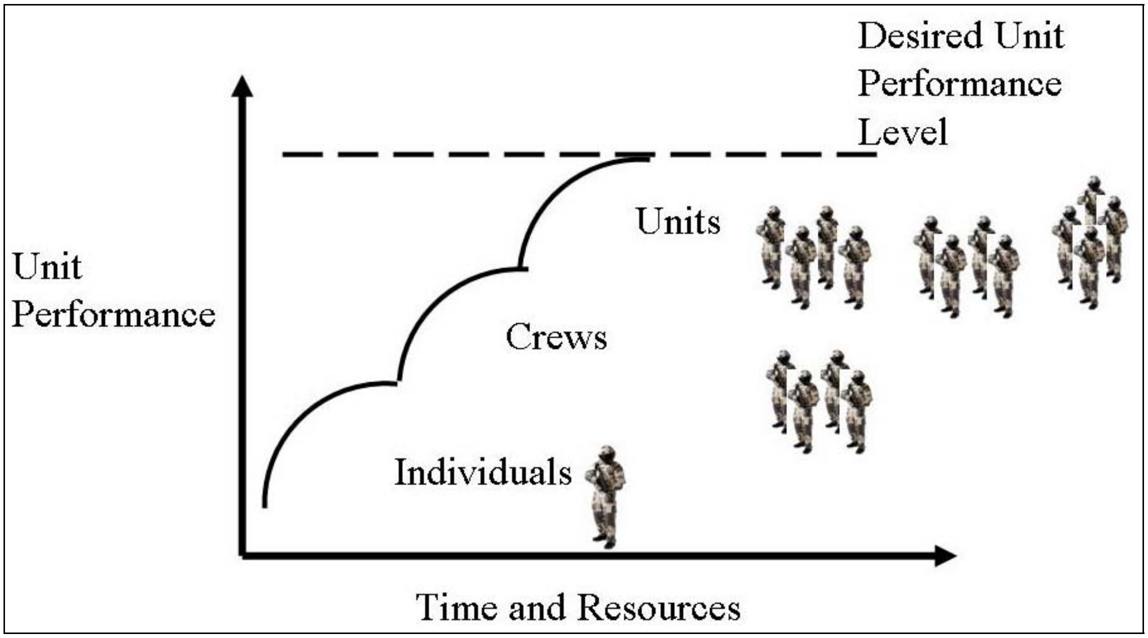


Figure 2. The development of organizational competence.

Recent research also emphasizes the importance of leaders in the development of effective crews. Kozlowski (1998) notes that leaders foster effective crew performance by (1) melding individuals into a coherent team, (2) fostering the development of an adaptive network of roles, and (3) assisting the crew in becoming a self-learning system. These three features—coherency, an adaptive network of roles, and a self-learning system—differentiate effective teams from a simple aggregation of individuals. Effective teams work together, learn as a group, and adjust their intra-team roles to reflect changing operational circumstances.

3.6 Training for Adaptability

One of the human dimension enablers for the Army's future force is individual and team adaptability. The primary reason for wanting adaptive individuals and teams is to cope with the uncertainty that is expected to characterize future operations. Individuals and teams must be able to make the necessary modifications to meet emergent challenges. In the AMD domain, crews must expect to modify or replace plans. They must expect to improvise.

Despite the recent emphasis on adaptability, little has been written about what it means to be adaptive, and even less has been done to foster the development of adaptive individuals and teams (Klein & Pierce, 2001). These authors also remark that much of what takes place during routine military training and operations has an effect counter to what is desired. That is, much of current training and operations acts to produce non-adaptive individuals and crews. Specifically, these aspects of traditional training include:

1. Training for mastery of task routine to the exclusion of problem solving
2. Using the crawl, walk, run method of training while avoiding trainee mistakes

In the first case, the usual emphasis of training is on mastering routines rather than adaptive problem solving. Klein and Pierce (2001) refer to the results of this practice as "experiosclerosis." Crews believe they are experts and combat ready because they are good at the routines, but the routines can prove to be a strait jacket during combat. Traditional individual and unit evaluation practices reinforced this mistaken belief on the part of crews and commanders at all levels by focusing only on satisfactory performance of routine drills. OIF BOIs specifically criticized Patriot training for its focus on crew drills while not addressing adaptive problem solving.

The crawl, walk, run method of training often means that training is not challenging or threatening. However, trainees learn from their mistakes. If they are not allowed to make and learn from mistakes, trainees do not develop the mental models that underlie effective problem solving performance. Klein and Pierce note that learning from both successes and failures is rapid. Accordingly, advanced scenarios must require trainees to face ambiguities and to reconsider options and re-plan. Crews must rehearse familiar scenarios of failure and strive to imagine novel ones. Failure, in present usage, means situations in which intended results were not achieved or adverse incidents occurred. Fratricides like those that occurred during OIF are examples of adverse incidents. While this approach might sound straightforward, it is not easily put into practice.

Klein and Pierce caution that while most crews can become adaptive, most will not achieve that level of expertise. The most likely reason for not becoming adaptive has to do with the requirement for long hours of deliberate practice and reflection discussed in section 2. Aside from trainee motivation, there also are other roadblocks to individuals and crews becoming adaptive. These have to do with the availability of master performers to serve as mentors, training equipment availability, adequate training scenarios, and a variety of routine bureaucratic constraints and administrative practices. It can be argued that in the current training environment, adaptive crews are likely to be the exception rather than the rule.

3.7 Mindfulness

The challenge facing the AMD community is developing units that are capable of sustained high reliability in a complex, unpredictable operational setting. Daunting as this challenge might seem, there is a class of organizations that have managed to do just that—maintain high performance in complex and unpredictable environments. Weick and Sutcliffe (2001) refer to such organizations as high-reliability organizations (HROs). Examples of HROs include air traffic control facilities, nuclear submarines, and aircraft carrier deck operations. As one FAA ATC manager put it: "99.9% operational reliability is not good enough for us. That would mean we would have several dozen 'noticeable' incidents each working day. And that would bring our operations to a complete halt" (M. Morrison, personal communication, August, 30, 2005).

Weick and Sutcliffe remark that HROs are characterized by ways of acting and leadership styles that enable them to manage the unexpected better than most kinds of organizations. These authors note that HROs manage the unexpected through five processes:

1. Preoccupation with failures rather than successes. Performance lapses and near misses are treated as symptoms that something is wrong with the system—something that could have severe consequences if a combination of lapses were to coincide at the same point in time. Consequently, HROs study incidents and near misses for what can be learned. They are wary of the potentially disastrous consequences of complacency and a drift into automatic processing.

2. Reluctance to simplify interpretations. HROs are reluctant to accept simplified explanations of potential trouble spots. They encourage critical inquiry across the organization, and are skeptical of "received wisdom" from outside sources who are often less knowledgeable about line conditions.

3. Sensitivity to operations. HROs are characterized by sensitivity to line operations. This is defined as a focus on understanding the situational aspects of organizations operations. They do not permit a disconnect between operations as viewed from the top and operations as implemented on the front line.

4. Commitment to resilience. HROs accept that no system is perfect. They expect that errors will occur and train their crews to recognize and recover from them. Following adverse incidents or near misses, HROs focus on system-wide fixes rather than item-by-item repairs. This requires a deep knowledge of the technology, the system, crews, and individuals. Consequently, HROs place a premium on expertise: personnel with extensive experience, recombination skills, and training.

5. Deference to expertise, as exhibited by encouragement of a fluid decision-making system. HROs recognize that rigid hierarchies are vulnerable to error. Rigid C2 structures are suitable for a stable world, but can be an impediment when adaptability is required. HROs, on the other hand, push decision making down and around in the organization. Decisions are made on the front line; authority migrates to the people with the most expertise, regardless of rank.

Together, these five processes produce an attitude of mindfulness or "intelligent wariness." To be mindful is to have an awareness of detail and an enhanced ability to identify and prevent errors that could escalate into an adverse event. How can an organization manage the unexpected? Weick and Sutcliffe assert that organizations can manage the unexpected by acting more like a HRO.

Desirable as it might be, acting more like a HRO is neither simple nor easy. For example, Weick and Sutcliffe caution that it is difficult for individuals and crews to remain chronically wary about their operations. Moreover, several of the HROs noted in the previous discussion (e.g.,

nuclear submarines and air traffic control) have had to create distinct supporting subcultures that sometimes put them at odds with their parent organizations (see Bierly, 1995). They have had to take and hold to the position that effective and reliable line operations come first and must be emphasized above broader organizational policies and practices. Their imperative is to make their operations as effective and robust as practical in the face of sometimes unpredictable engineering, human, and operational vulnerabilities.

4. A Path Forward for AMD

4.1 Overview

The final section of the report concerns a path forward for AMD. In developing this section, it is not our intent to tell others their business. That is, it is not our intent to get deeply into Army or AMD training design and development processes, other than to suggest areas where improvements to increase effectiveness and organizational reliability are indicated. These suggestions for improvement are taken from the human performance and training literature as well as from lessons learned in parallel organizations. A parallel organization is one engaged in operations and training for jobs similar to AMD operator-controllers. Again, the focus of the following discussion is training for ABO.

The discussion to follow is also presented in two parts: (1) training for routine operations and (2) training for adaptability. Training for routine operations addresses enhancements directed at improving effectiveness and reliability in situations involving little ambiguity or uncertainty. The intent here is to develop personnel and crews well practiced in the basics of AMD operations. Training in advanced aspects of AMD operations such as coping with unreliable automation must be based on a firm foundation in AMD and system fundamentals.

Training for adaptability is based upon competent baseline performance by individuals and crews. It might be termed advanced training for situations that are non-routine or out-of-the-ordinary. As the name implies, it is intended to foster the adaptability and mindfulness necessary to cope with unreliable automation and the inevitable surprises of combat operations.

4.2 Training for Routine Expertise

Our observations of AMD training and operations plus material from the literature cited in the previous sections suggest six areas for improvement in AMD training for routine operations. These points are listed and discussed as follows.

1. Job and task analysis. We remarked earlier that training design can be no better than the JTA on which it is based. Training developers must understand the performance context

and what trainees must learn to perform competently in that environment. This goal cannot be met if the JTAs upon which training are based are simply updates of previous JTA material. The first and second reports in this series (Hawley, Mares, & Giammanco, 2005; Hawley & Mares, 2006) emphasize that automated operations present a different performance setting from that associated with traditional manual control. These differences must be reflected in training and job aiding. To the extent these performance changes are not addressed during the JTA and subsequent training development, the resulting training will be inappropriate and sometimes ineffective vis-à-vis actual performance requirements.

2. Scenario content. We noted previously that in training for a job like AMD operator-controller, the scenario is the curriculum. This means that training scenarios must be carefully scripted to cue the decisions and performances indicated in the JTA as being critical. Training managers must also be aware that training scenarios have a limited shelf life. After more than about three uses with the same group of trainees, they lose their training value. Trainees recognize the scenario and begin to "game" it. Gaming scenarios destroys their learning value, since gaming rather than learning becomes the objective of the exercise.

3. Performance standards. Training managers must attend to the development of operational performance standards for scenarios and for success at the various certification levels. Skill checks for individual tasks or portions of tasks are important in skill development, but they are not sufficient for judging job competence. Standards must be objectively stated in terms of successful performance against benchmark scenarios having stated performance objectives and known difficulty levels. In ABO training, the whole defined as competent job performance is more than the sum of its individual task parts. Standards must also be applied uniformly in institutional and unit training. Trainers and commanders must know where the bar defining competent job performance is set.

4. Time to reach desired competency levels. Time to train to desired competency levels is one of recurring problems in Army and military training in general (DSB, 2003). Training times must be determined on the basis of how long individuals take to reach desired competency levels. A situation must not be allowed to exist in which training is shoehorned into available times or is fixed arbitrarily on the basis of bureaucratic or administrative considerations. If such considerations are permitted to dictate training times, the result will be incomplete training and inadequate on-the-job performance. In training, there is no way to escape the fact that you get what you pay for.

5. Qualified instructors. There is an old adage that it is hard for an apprentice to learn if there are no masters. Personnel assigned to training jobs in the institution and in units must be expert job performers (EJPs). An EJP is a SME who also has recent and relevant on-the-job experience. Their job is to teach trainees how to do the job, not just to teach them

about the job. Consideration must also be given to the teaching ability of potential instructors. Roth (1998) cautions, for example, that system experience is not a guarantor of effective instructional capability. Also, Norman (1993) cites results indicating that a course's reputation is a major determinant of trainee motivation. If a course has a good reputation that word will spread and trainees will come to the course motivated and prepared to learn. On the other hand, if a course has a bad reputation, that fact will be reflected in an unwillingness to come or attend to the material. Trainees will use any excuse to get out of attending. Requiring attendance will not always result in effective learning.

6. The AAR process. A generally accepted axiom of experimental psychology is that no learning takes place in the absence of feedback. This simple fact underlies much of the success attributed to the Army's training at Combat Training Centers (CTCs) such as the National Training Center (NTC). At the CTCs, considerable effort goes into the post-exercise AAR. Training design can be exceptional; scenarios can be great; but if the AAR process is deficient, learning will be inadequate. The same relationship applies to lower echelon training conducted in institutions and units outside the CTC context. Good AARs go well behind a mere replay or recap of what went on. They consist of a penetrating behavioral critique that is designed to change the way trainees think about the performances in question. Trainees must be told not only that a particular performance was right or wrong, but also why that performance was right or wrong. Good AARs are critical to tuning the mental models upon which future performance will be based.

4.3 Training for Adaptive Expertise

As noted previously, training for adaptability is intended to foster the ability to think outside the box defined by routine crew drills. It is intended to provide operator-controllers with the ability to cope with unreliable automation and the inevitable unforeseen events that characterize combat operations. In one sense, the mechanisms underlying training for adaptability are straightforward. As the DSB recommended, trainees should face confusing and complex scenarios that contain unbriefed surprises. Such scenarios must push trainees and crews outside their comfort zone and stress problem solving over routine operational processes. Crews working together must recognize when a situation is not ordinary and requires problem-solving intervention. If there is a key to achieving this result, the operative word is expertise. Not to confront issues associated with expertise as defined in this report invites a drift toward automatic processing and the kinds of performance problems that led to the Patriot Vigilance effort.

As desirable and straightforward as training for adaptive expertise might seem, producing adaptive individuals and crews will not be a simple undertaking. We cite again Klein and Pierce's (2001) caution that most crews can become adaptive, but most will not. Why not? In our observation, three roadblocks stand in the way:

1. Time and job progression practices
2. Training quality
3. Trainee motivation

First, achieving adaptive expertise will require more time for training than the Army has traditionally allocated for AMD operator-controller job preparation. Simply put, there is no way to avoid the 5,000 hour rule that applies in other high-skill situations. Further, intra-unit job progression patterns will have to change. Operator-controller trainees will have to spend an extended period in an apprentice status while they acquire the skills and experience necessary for effective job performance. Unit metrics regarding qualified crews will have to change, and it is not certain that current personnel management practices and concerns can accommodate such a requirement.

Second, many qualitative aspects of operator-controller training will have to change. To begin, training for what we have termed routine operations will have to be more rigorous and performance-oriented than at present. Training content and scenarios must reflect job requirements, and standards must be rigorously applied across the board. Introductory, baseline training will have to be followed by crew-oriented training that emphasizes fluid decision-making within an adaptive network of roles. This will require intact crews, special training such as CRM, competent instructors, and—above all—time to form this collective expertise. Crew leadership also is important to adaptive team performance.

Third, trainees must be motivated to develop the deep expertise in AMD technology, weapons systems, and operations necessary to inform the decision processes that characterize being adaptive. This is the reflective aspect of job preparation. As we noted in the previous section, the proper setting for such preparation is self-directed study and professional military education. Trainees, commanders, and the general Army culture must accept that preparation for a job like operator-controller involves no less professionalism than preparation for command or any other high-skill job. The topics and focus are different, but the preparatory requirements are similar. We have discussed them extensively in this report.

An example from the Army Aviation community might clarify and illustrate this third point. Army Aviation uses a special Warrant Officer career progression track to increase professionalism and expertise among enlisted aviators. Warrant Officer aviators are officers, are highly selected, are granted honor and deference by all concerned, and are *expected* to be highly trained professionals who operate at the highest levels of expertise. Moreover, it is anecdotally reported that instructor pilots demand more of Warrant Officer students than of Commissioned Officer students (D. M. Johnson, personal communication, January 10, 2006). Commissioned Officer students eventually grow up and become staff officers, administrators, and commanders; but Warrant Officer students develop as expert aviators and remain in this role throughout their career. The emerging job of an AMD operator-controller is no less demanding than that of an

Army Aviator, and skill and professional development for these personnel must be approached in a similar manner.

4.4 The Training Challenge

Achieving the objectives cited in the previous sections will not be easy. To begin, commanders and training managers must recognize that the Army's crew drill mentality is a major part of the problem associated with preparing Soldiers for knowledge-intensive jobs. As Klein and Pierce (2001) caution, the crew drill mentality discourages adaptive problems solving and almost guarantees a drift toward automatic, unthinking processing. Its mantra is, "This is the way we do it, and any other way is wrong." Crew drills are appropriate for some job situations, but inappropriate in others. They are not suitable for ABO training.

In the report *Training for Future Conflicts*, the DSB asserts that the future will require that more of our people do new and more complicated things (DSB, 2003). That same report also remarks that meeting this challenge amounts to a "qualitative change in the demands upon our people that cannot be supported by traditional training practices" (p. 6). The DSB report concluded that training transformation to support warfare transformation will be a challenging undertaking.

Our assessment of the path forward for AMD training is consistent with the DSB's conclusion. Technology and the operating environment are driving changes in weapons systems, and these combined changes require a change in training concepts and practices. Not to change means that AMD training will become increasingly unsuited to operational requirements. The 2003 DSB report cautions that training failures can negate promising hardware and technologies. That warning applies directly to the technology-intensive AMD situation.

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